For interesting, anti-skid surface textures, try

Exposed Aggregate Pavements

BY LYNN M. F. HARRISS
Landscape Architect
Oakland, California

EDITOR'S NOTE

The method of exposing aggregate described in this article is just one of several successful techniques which have been developed. Retardant coatings for direct application to flat-work surfaces, and to forms in the case of vertical surfaces, are also being used with good results. CONCRETE CONSTRUCTION hopes to do an article on the use of such coatings in the near future.

FLAT CONCRETE, in floors, decks, walks and roads has always been respected as a rugged and utilitarian material. But until fairly recently most people took a rather dim view of concrete pavement in areas where aesthetic appeal was of prime importance. From marble to flagstone, from polychrome tile to common brick, almost anything was used to avoid the plainness, the cold color and monotony of concrete.

Nowadays things are quite changed. Contemporary architecture emphasizes the beauty of large spaces in correct proportion, but with a minimum of surface ornament and gewgaws. The great trend is toward beauty through functionality. And the new, fadeproof colors, the efficient sealers, and the many imaginative ways of handling surface textures which have been devised, have brought concrete into its own, not only for its utility, but for its richness of color and interest of texture as well. It has become an almost irreplaceable element even in the most elaborate developments, both indoors and out.

Texture variations include simple brooming, sacking, grooving and other miscellaneous surface deformations with the finishing tools, and also the pebbly textured exposed aggregate finish. They are all good if not overdone, and the exposed aggregate finish is perhaps the most satisfactory and widely-used of all. It has the great advantage of presenting the hardest part of the mix —the stone aggregate—for a wearing surface. This means that the "Tooth", or anti-skid qualities of the surface, will tend to remain effective over a much longer period than most other surface deformations (which have a bad habit of wearing down through use to a smooth, sometimes slick, surface). It presents a surface which will grip automobile tires and yet be entirely comfortable to the wearer of high-heeled shoes. Finally, the qualities of color and texture may be varied through a wide range for special and harmonious effects. The color and size of the topping course of aggregate can be made to vary from fine white dolomite chips through all the varying-colored water washed gravels, to chips of ceramic tile and crushed brick. The mix itself may be colored to contrast with the aggregate to be exposed. Here we have a truly versatile way of bringing concrete paving into harmonious

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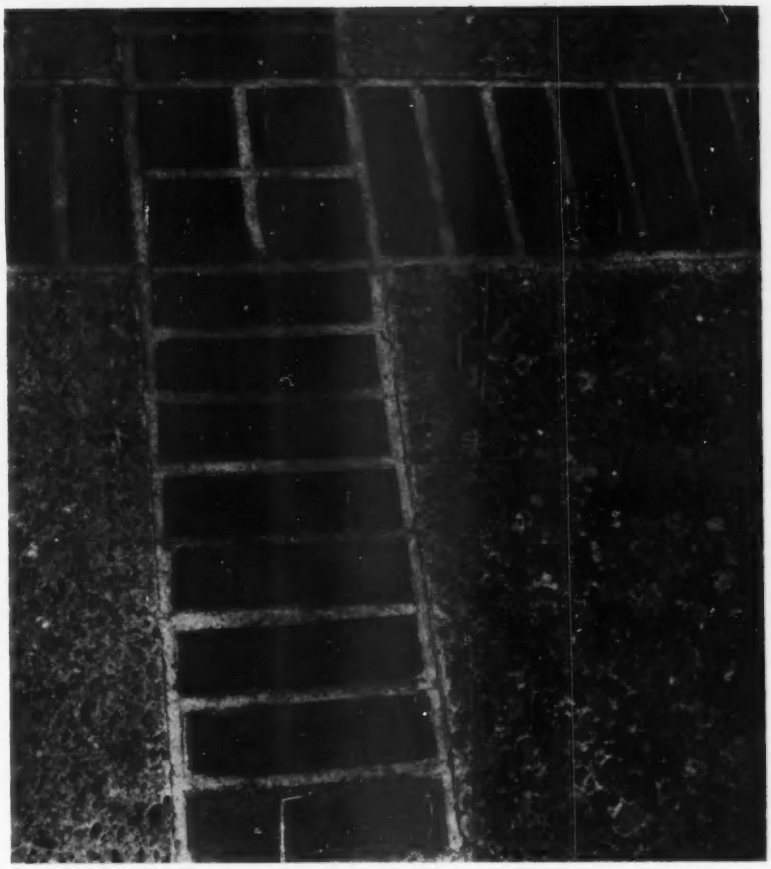
opposition to almost any conceivable composition.

The technique of producing the finish is essentially simple, but may turn out to be unexpectedly complicated if certain basic conditions are not observed. Frequently the material sets up faster than expected, or in irregular patches. Sometimes the process of exposing the aggregate is attempted too soon, resulting in a general mess of humpy concrete. Sometimes it is attempted too late, and a muriatic acid solution has to be used, sometimes resulting in a spotty surface and often inflicting damage on adjacent plants. Sometime over-zealous workmen armed with stiff steel wire brushes will dislodge sizable pieces of aggregate, leaving gaping holes, unpleasant in appearance, and dangerous traps to high heels.

Prior to pouring, the topping aggregate should be readily available in several piles adjacent to the work. If ½-inch pea gravel is used, about two tons will be required per 1000 square feet of surface. Other materials will vary accordingly. Two push brooms, one a fine hair broom, and the other a medium-to-fine bristle broom, should be available, in addition to the standard concrete finishing tools. Hose from the nearest available water supply should reach to every part of the work.

Following each part of the pour, immediately after screening, the topping aggregate is scattered over the surface so as to make a fairly complete covering, one pebble deep. As for the whole operation, it can be described in the following paragraph, which may be used as a part of the Special Provisions when specifying this type of work:

"EXPOSED AGGREGATE SURFACE. Clean pea gravel shall be scattered over the surface of the freshly-screeded concrete so as to produce a layer of partially imbedded particles, not more than one pebble deep, but close enough so that pebbles are not spaced greater than their own diameter apart. Generally when surface water has disappeared, float the surface, imbedding the pea gravel pebbles in the fresh concrete so that they disappear completely. Do not carry on this floating operation any more than is necessary to level out the surface. After concrete sets up enough so that an average man can walk on it without indentation (may average 2 hours on a warm day), a slow stream



Brick edging is used for breaking up large formal areas.

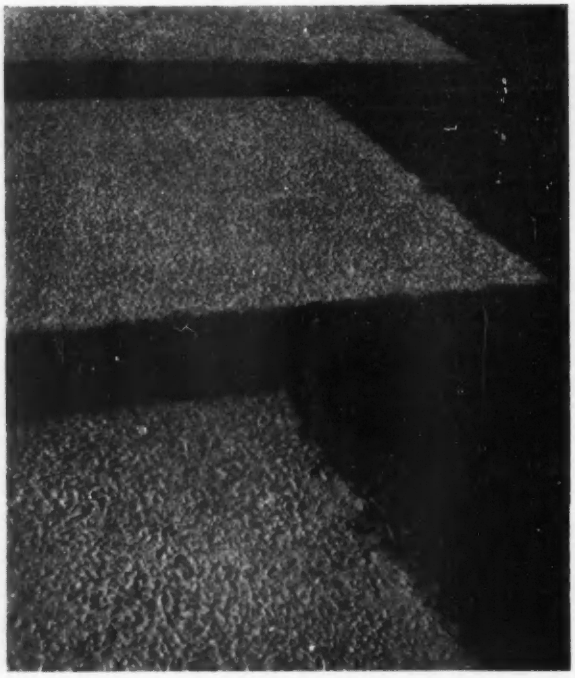
After floating pebbles into surface and allowing a reasonable time for set-up, broom the surface gently.

Washing off broomed material may be done with or without the nozzle spray shown here.

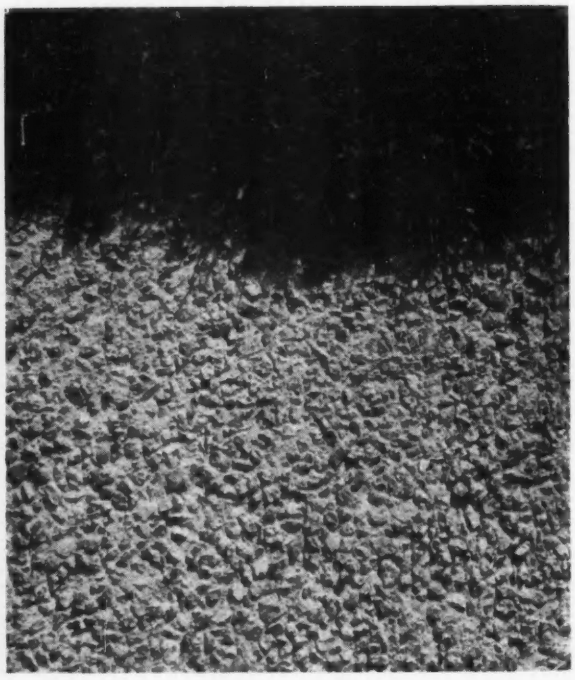
of water shall be applied to the surface by one man, working from the highest elevation downward, with a second man gently brooming the surface with a hair broom (or, if directed, with a fine bristle broom), leaving a surface of clean pebbles, about one-third of their respective volumes projecting from the solid concrete."

As noted in the previous paragraph, a certain amount of judgment must be used as to which broom should be used, and how deep the brooming and washing away of the concrete should go. The two brooms are a must, because the best jobs result from doing the exposing process at exactly the correct time, using the hair broom. However, if the work sets up just a little too much, it will be necessary to employ the bristle broom, and perhaps use it rather vigorously, in order to achieve the result desired. In this connection, one rule of thumb should be followed: **take it easy on the broom, but use plenty of water.** For northern latitudes it is especially important to broom and wash only enough to expose the very tops of the pebble, in order to minimize the loosening effect of freezing. In such areas, the application of at least two coats of silicone sealer is recommended. END

"Easy on the feet"—exposed aggregate rectangles create an informal approach to a swimming pool.

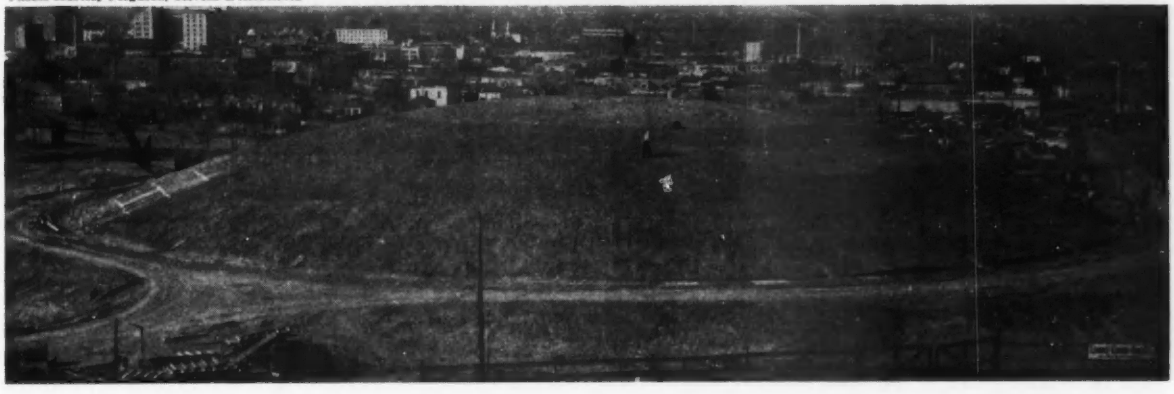


The desirable texture of the exposed aggregate is shown here in detail.



This photo shows the earth mound in place and fine grading operation nearly completed. You will note at the left edge of the dome the plywood forming which was used for the outer portion of the dome (see arrow). You will also note the concrete columns extending through the earth field around the perimeter. These were placed before the completion of the mound form. The method of pouring the dome on earth was investigated and proved to be the most economical. This was true in part due to the location of the dome on the highest portion of the site. Natural grade at this point was from eight feet under the spring line of the dome.

Photos courtesy Ferguson, Stevens & Associates



This novel reversal of the normal sequence of construction operations saved $50,000 in forming and shoring costs on the Albuquerque Auditorium

Poured First, Then Excavated

LAST JANUARY (page 14) we ran a news photograph and a brief caption telling a little about the novel build-first-then-excavate technique used in the construction of the new dome-roofed civic auditorium for the city of Albuquerque, New Mexico. It evoked considerable comment among our readers, and a number suggested that there might be enough interest in the technique to justify telling a more complete story. Here it is.

As the photos show, the concrete for the 218-foot diameter thin-shell dome roof was poured on a natural mound of earth as a means of saving costly formwork and shoring normally required for this type of construction. The estimated saving on the $1-million project was about $50,000.

This ingenious expedient was encouraged by the fact that the mound was there to begin with, and it would have been necessary to remove it anyway. The architects were just alert enough to sense the possibility of turning a site liability into an asset by the simple expedient of changing the normal sequence of construction operations.

Their first step was to excavate a deep trench clear around the mound. Twenty-two spread footings and rectangular columns ranging from 24 to 42 feet in height were formed and cast in the trench. Then the trench was backfilled and the mound was shaped and surfaced to receive the concrete for the dome. Rotating templates were used to make the naturally irregular earth mound conform to the desired 256-foot radius spherical dome having a 23-foot rise from spring line to center. Low spots were filled in with a thoroughly compacted mixture

ABOVE, the area of the pouring of concrete for the shell. The large amount of reinforcing shown in this picture was used to resist compressive stresses in the outer ring introduced by post tensioning the ring. This placed the entire structure in equilibrium and when the earth was removed there was only three-eighths of an inch deflection at the center and substantially none in a horizontal direction at the edge of the ring. Because of this equilibrium there should theoretically be virtually no lateral movement in the columns due to expansion and contraction.

BELOW, shows early stages of excavation work under the dome. The grade as shown in this photograph is approximately lobby floor line. As soon as a clear area was free under the dome bulldozers were used to remove the bulk of the earth into loading chutes.

of sand and gravel and natural binder, and the entire area was finished off with a layer of fine stone which was carefully consolidated and rolled. This surface was used to form the under side of the shell for all except a 30-foot wide outer belt which was to be left exposed in the completed structure. To obtain the desired texture of concrete surface in this area, it was lined with sheets of ¾-inch thick plywood.

Inside a 160-foot diameter circle in the center of the dome the shell concrete is 5 inches thick. Outside this circle the concrete gradually thickens to meet a 24-inch deep by 36-inch wide ring girder. Reinforcing steel was placed in the shell both radially and circumferentially.

The shell concrete was placed starting from the outer circumference, with the first of four concentric pours being chuted directly from ready-mix trucks. A crane was used in placing the second and third lifts, and a crane-to-hopper-to-buggy sequence was used for the final lift. About a thousand cubic yards of ready-mixed concrete went into the shell proper, and this portion of the job required about ten days to complete.

After the shell concrete had set the heavily-reinforced ring girder was prestressed with high-strength wire prestressed to 140,000 psi. The wire (655 turns in all) was wound into a channel cast into the outer face of the ring girder, the tensioning being accomplished by means of a tractor-drawn drum which applied the stress with a dynamometer. Each turn was anchored individually and each layer of wires was grouted before the next was placed.

According to the designers, the func-

tion of the prestressed ring girder is to place the entire structure in equilibrium. That this was actually accomplished is borne out by the fact that as the load of the roof shell was gradually transferred from the earth mound to the ring girder, the measured deflection at the center of the shell was only three-eighths of an inch, and there was substantially no horizontal movement at the edge of the ring. Because of this equilibrium it is believed that there will be little or no lateral movement of the columns due to expansion and contraction.

After completing the stressed collar by filling the channel with concrete, shovels and bulldozers began the man-sized job of removing some 120,000 cubic yards of earth beneath the shell. Somewhat like a lift-slab working in reverse, the huge dome and its supporting ring girder and columns slowly erupted from the ground. As soon as adequate working areas beneath the dome had been cleared with front-end loaders, bulldozers were used to push the bulk of the earth into loading chutes.

The remaining portions of the structure, including 8-foot encircling corridors at the back and sides, and lobby, mezzanine and service rooms at the front, were all built by conventional methods. The total floor area is approximately 70,000 square feet and there is a permanent seating capacity of 3,500 plus room for an additional 2,500 temporary seats.

The contractor for the project was Lembke-Clough & King, Inc., and the architects were Ferguson, Stevens & Associates. Albuquerque Gravel Products Company supplied the ready-mixed concrete. END

Pictured above is a later stage of the excavation with the earth down to approximately balcony floor level. In the right foreground you will note the foundation walls for the vomitories leading to the arena area.

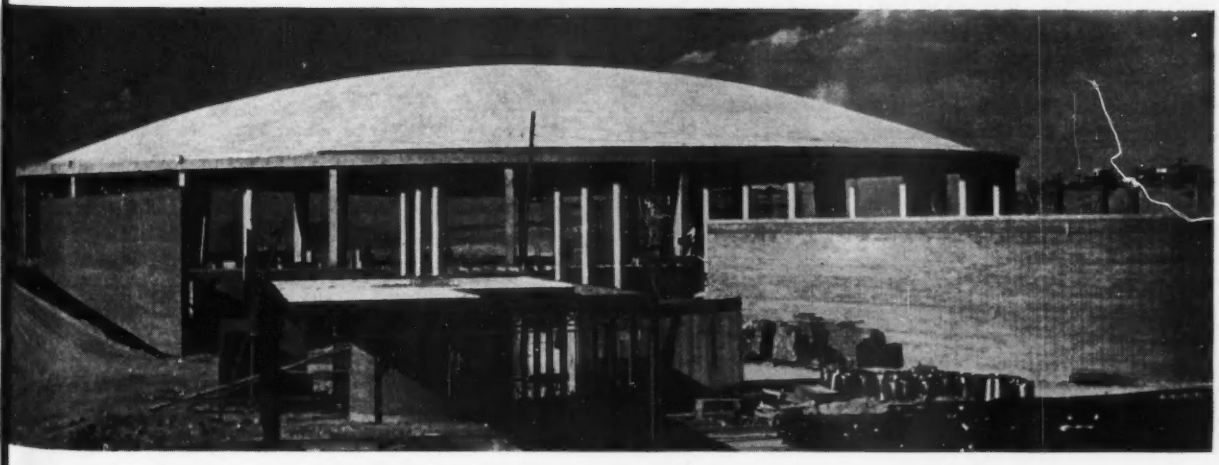


Photo courtesy of Chain Belt Company

Here is a pumping unit, similar to the one used for the Topeka parking garage, being charged from a ready-mixed concrete truck.

Topeka's Parking Garage

Pump placement of 5500 cubic yards of concrete on this construction project resulted in some worthwhile economies.

CONCRETE CONTRACTORS everywhere will be interested in some of the handling, placing and forming techniques used for a recently completed mainly-concrete, 430-car parking garage project in Topeka, Kansas. Structures of this general type are being built in increasing numbers all over the country to help solve the urbanite's chronic problem of what to do with his automobile in congested down-town areas. Since concrete has probably more all-around appeal as the primary material for buildings of this type than any competitive construction material, it is safe to predict that in the years just ahead concrete construction men will have both the need and the opportunity to familiarize themselves with some of the methods employed on the Topeka job.

The structure is of reinforced concrete throughout and a continuous ramp design is used from ground level up through the roof. Including the basement and the roof, there are six parking levels in all. Because of the restricted site and other considerations, it was decided to place as much of the concrete as possible with pumping equipment. Approximately 5,500 cubic yards of concrete was placed in this fashion, or roughly 95 per cent of all the concrete used on the job.

The pump used on the Topeka job will handle all commonly used mixes with aggregates up to 2 inches, although larger models are available that will handle 3-inch aggregate. The pumping cycle of the unit keeps the pipeline completely filled to assure a continual flow of concrete from the discharge end of the line. It is equally effective whether pumping on a level or straight up, the vertical limit being approximately 100 feet and the horizontal about 800 feet. Larger machines have somewhat higher limits, and greater distances may be handled by the use of two pumps in series. Capacities range from 15 to 20 cubic yards per hour for the machine used on the Topeka job to 50 to 65 cubic yards per hour for the larger double units.

The pumping equipment was set up about 12 feet clear of the site and materials were hauled to this location by truck as needed. Some careful preliminary planning went into the location of pump pipe runs to achieve maximum use of each setup. Pipe runs were supported on "A" frames across

the floors to assure that surge from the pump would not affect the formwork.

The contractor believes that the decision to pump resulted in several important economies, such as the elimination of major hoisting equipment and buggy runways. He reports that there was also an important labor saving in placing the concrete. Where a conventional handling system would probably have required three finishers for setting screeds, striking off and finishing, the rough placement and initial consolidation on this job were usually handled by a crew of two laborers, and the final consolidation by one man with a vibrator.

Although only one man on the entire job had any claim to previous experience with pumping concrete, no difficulty was encountered in teaching the necessary techniques to other personnel as the job progressed. Quantities of concrete required for any particular stage of the work were figured as closely as possible to hold waste to the minimum. Waste tanks were located on each level of the structure to handle excess concrete as well as water left in the lines at the close of operations.

A variety of pipeline lengths and bends enabled the contractor to pump concrete anywhere on the job by lengthening the pipe, shortening it, or turning it in any direction.

A view of Topeka's Municipal Parking Garage taken from the second level, showing the columns, beams, and overhang.

The 6-inch thick concrete for the basement floor was reinforced with 6-inch by 6-inch by No. 6 wire mesh, and divided into about 20- by 30-foot contraction joint areas by sawing. Because of the sloping roof design the contractor used adjustable shoring to support beam and joist forms. The cost of the shores, some of which were 14 feet high, was offset by a saving in labor. Floors beneath any pouring operation were protected with a sand cover. A wood float finish was used for all floor surfaces except on two 10-per cent grade ramps on which a very coarse broom finish was used to provide maximum traction.

Rustication joints on the exposed faces of the architectural concrete were spaced to conform to standard material lengths, thus making it possible for all material joints to occur at rustication joints. To permit maximum reuse of forms, major interior beams and all spandrel beams and curb walls were uniform in size.

The contractor elected to use ¼-inch thick masonite, screen side to the concrete, to line the forms of all spandrel beams and curb walls. The resulting rough-textured finish provided an excellent surface for the grout clean-down finish which was given to the exposed architectural concrete. Round, plastic-lined fibre forms were used for the columns.

The strength specified for the concrete was 3,750 psi at 28 days. Three to 6 per cent air was entrained with a commercial admixture, and calcium chloride was added to the mix during cold weather operations. The mix design called for the addition of "fine" fines to provide exposed surfaces of maximum density.

The concrete work for this project was handled by the general contractor, Douglas Construction Company of Topeka. The architects were Ekdahl, Davis and Depew, also of that city. Planning and consulting service were provided by the Ramp Buildings Corporation of New York. END

This view, which also appears on the cover, shows reinforcing in place ready for pouring.

Not often are the versatility functionality and beauty of concrete construction all so ably demonstrated in one small area as in this . . .

Helical Concrete Staircase

SHOWN ON THIS PAGE as well as on the cover of this issue, are two photos covering the construction of a remarkable helical staircase for a wholesale milliner's showroom in London, England. It was the purpose of the architects to provide not only a pleasing central link between two showroom floors, but also to create a dramatic approach for mannequins as they turn in their descent from the changing rooms to the showroom floor.

The staircase spans the full vertical distance of 13 feet from floor to floor without any intermediate support. The flight is 4 feet 8 inches wide and it turns through an angle of 294 degrees. It was designed as a helical beam, and the minimum thickness of the concrete is 7 inches. Longitudinal bars and transverse links were used to resist torsion, and a reinforced concrete hinge was provided at the bottom of the flight to prevent bending forces from being transmitted to the floor slab. The upper end of the staircase, however, was made continuous with the floor slab at that level.

To simplify bending the longitudinal reinforcing, straight pieces of small diameter bars were used that could be sprung into position. As a result it was necessary to place bars as close as 1½ inches center-to-center, but this had the advantage of reducing bond stresses. The aggregate was graded carefully from ¾-inch down to facilitate placing and compacting the concrete. An electric hammer was used to assure thorough compaction.

The ground-floor slab and the lower part of the reinforced concrete hinge were placed and finished ahead of the staircase slab. Concrete for the staircase itself was placed in a continuous operation from top to bottom. including the adjacent portion of the floor slab above.

Formwork was removed nine days after the concrete was placed, starting at the middle of the span and gradually increasing the unsupported length in both directions. Deflection due to the weight of the slab was measured by independently supported dial gauges placed in contact with eight of the treads at the centerline of the flight.

Structural design work for this interesting project was carried out by R. L. Borqui & Partners, consulting structural engineers. Concrete Construction magazine is indebted to them for the excellent photographs, and to *Concrete and Constructional Engineering* magazine for the information concerning the project. END

Here the stairway is seen after the forms had been removed. The concrete was allowed to cure nine days before the forms were stripped.